

Analysis of Breast Milk to Assess Exposure to Chlorinated Contaminants in Kazakhstan: PCBs and Organochlorine Pesticides in Southern Kazakhstan

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Organochlorine pesticides (OC) and polychlorinated biphenyls (PCBs) were measured in samples of breast milk taken from 92 donors representative of regional populations in southern Kazakhstan. The World Health Organization protocol for assessing levels of chlorinated contaminants in breast milk was followed. The most prevalent OC residues were β -hexachlorocyclohexane (β -HCH), *p,p'*-DDE, *p,p'*-DDT, hexachlorobenzene, and α -HCH. The measured levels of β -HCH were among the highest reported in the published literature. Data from Aralsk, near the Aral Sea, indicated continuing DDT exposure. Overall PCB-toxic equivalent levels (22 pg/g fat) were similar to those reported in industrialized European countries. PCBs were highest in Atyrau in the Caspian oilfields. **Key words:** Aral Sea, breast milk, DDE, exposure assessment, β -HCH, Kazakhstan, organochlorine pesticides, PCBs.

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Organochlorine pesticides (OC), polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) were measured in samples of breast milk and infant and adult foods collected from regional populations in southern Kazakhstan over a 4-week period beginning in February 1994. The study arose from two facts: infant mortality in Kazakhstan is high (40/1,000 live births), and breast feeding, which improves infant survival, was thought to be declining. In-country health practitioners attribute this decline to concerns about possible contaminants in breast milk.

Sources of these chlorinated contaminants include agricultural uses of pesticides, particularly on cotton in the South, historical fish consumption from the heavily contaminated Aral Sea region, and use of PCBs in industrialized areas. Kazakhstan, like many member nations of the former Soviet Union, is grappling with issues of environmental degradation.

Several public health and environmental benefits result from monitoring breast milk for contaminants. First, breast milk samples offer a convenient and noninvasive means of monitoring human adipose tissue for the presence of persistent, lipophilic xenobiotics. Second, such contaminant data provide insight into environmental conditions, adult body burdens, and historical human exposures. Third, these measures complement general environmental monitoring and provide a more accurate assessment of human exposures. Finally, the dose to the nursing infant can be estimated.

In this paper, we will discuss residue levels of PCBs and OC pesticides in breast milk samples.

Materials and Methods

Agricultural patterns, pesticide use, major industrial processes, dietary habits, and work practices of ethnic, cultural, and religious populations within Kazakhstan were evaluated to identify potential local sources of exposure to target analytes.

Study design. Breast milk donors were accessed through regional maternal and child health clinics (MCHC), as arranged by the Kazakhstan Ministry of Health. Sufficient donors (10–15) were recruited at each MCHC to assess contaminant levels among the region's subgroups (e.g., Kazak/Russian, fish eaters, etc.). Breast milk samples (92 donors) as well as representative foodstuffs (weaning foods, dairy, fish, fat) were collected from seven sampling sites.

Sampling sites were selected to reflect the major industrial, agricultural, and population centers of southern Kazakhstan. Background populations (urban, rural) as well as high-risk geographic regions (Aral Sea, Caspian Sea, cotton-growing, or fish consumption regions) were targeted. Four populations were sampled at seven MCHCs (see Figure 1): 1) large urban centers, including Almaty, the capital and government center of Kazakhstan, and Shymkent and Qzyl-Orda, industrial cities of the south; 2) an agricultural region whose fish consumption is elevated for Kazakhstan, Aralsk; 3) a petrochemical region with elevated fish consumption, Atyrau; and 4) small rural populations, Zhetisay and Kirov, two neighboring agricultural villages in a cotton-growing region (cotton is a crop that typically receives OC pesticides). These two villages were combined to form the rural site.

The exposure assessment model followed the World Health Organization, Regional Office for Europe (WHO/EURO) protocol for examining chlorinated contaminants in breast milk, including selection criteria for donors (first time mothers in apparent good health with 2–8 week-old infants) and sample collection procedures (1). Donors completed an informed consent form and an exposure assessment questionnaire, and manually expressed up to 100-ml samples of breast milk into analytical-grade glass containers with teflon-lined caps. Samples were frozen immediately and maintained at -20°C until analysis (1). Chain of custody procedures were maintained throughout the study (2). Representative samples of weaning foods, fish, and dairy products were also collected from the various sites.

Exposure assessment questionnaire. Modified from the standard WHO questionnaire (1), our questionnaire determined the health status and breast feeding pattern of the infant; the health status, food frequency pattern, smoking status, medication use, and 20-year residence history of the mother; and the 10-year work history of the mother and father.

Target analytes. Target analytes selected were tri- to deca-substituted PCBs, including dioxinlike PCBs, 2,3,7,8-substituted PCDDs/PCDFs, and the major OC pesticides, including the DDT, chlordane, and

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hexachlorocyclohexane (HCH) families. All of the selected target analytes have long half-lives and are known to bioaccumulate in adipose tissue. Human milk contains 2–4% fat and is an appropriate matrix to assess body burden of lipophilic chemicals.

Composite samples. Analysis for OC pesticides requires small (10 ml) volumes and could be performed on all individual samples. PCDD/PCDF and congener-specific PCB analyses require large (100 ml) volumes and can be performed either on large-volume individual samples or on composites of individual samples of lesser volumes. Compositing criteria were (in decreasing importance) geographic region (clinic), ethnicity (Kazak/Russian/other, reflecting cultural/dietary habits), fish consumption, and region of mother's residence (agricultural/industrial/urban).

Of 92 women who provided a milk sample, 17 provided sufficient volume (100 ml) to permit analysis of PCDDs/PCDFs and PCBs. Samples of lesser volumes were combined into 18 composites for PCB analysis, each composite containing equal volumes of milk from contributing donors. The number of donors per composite ranged from 2 to 8, with a mean of 2.9. A total of 35 samples (17 individuals and 18 composites) were analysed for PCBs. A total of 76 donors provided sufficient volume (10 ml) for analysis for OCs.

Analytical methods. Analysis of breast milk and cow's milk for the full panel of target analytes (OC pesticides, PCDDs/PCDFs, and PCBs) required approximately 100 g sample (2,3). Samples were spiked with internal and surrogate standards and extracted with 2:1:1 ethanol:hexane:ethyl ether in the presence of sodium oxalate. An aliquot of the organic phase, corresponding to 10 g sample, was passed through gel permeation chromatography (GPC), concentrated, and analyzed for OC pesticides by gas chromatography-electron capture detector (GC-ECD). The remainder of the organic phase was loaded onto an AX-21 carbon column (Anderson Development Co., Adrian, MI), eluted with 6:4 dichloromethane:hexane, and collected as fraction I. Toluene elution of the carbon column in the reverse direction resulted in fraction II. Fraction II was cleaned up with silica gel and alumina columns and concentrated; high resolution gas chromatography/high resolution mass spectrometry (HRGC-HRMS) was used to measure PCDDs, PCDFs, and PCBs 77, 126, and 169. Part of fraction I was used for gravimetric fat determination. After digestion with H_2SO_4 and silica gel and alumina clean-up, another portion of fraction I was used to quantitate levels of 80 PCB congeners by

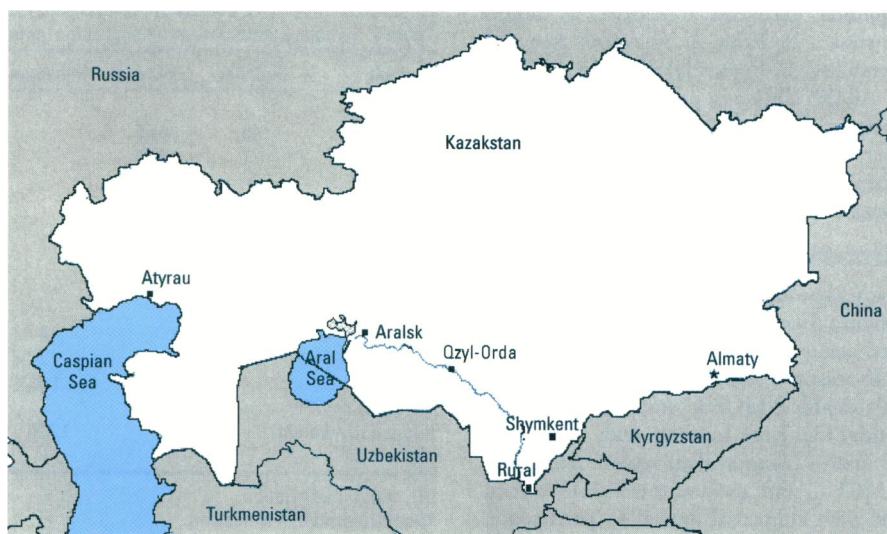


Figure 1. Map of Kazakhstan showing the areas sampled.

HRGC-HRMS. Residue levels were expressed as picograms per gram lipid. Detection limits for OCs were 10 ng/g fat; for PCBs, detection limits ranged from 5 to 100 pg/g fat for the various congeners.

Fish samples were processed in a meat grinder, freeze dried, homogenized with sodium sulfate, spiked with internal standards, transferred to a potassium silicate/silica gel/sodium sulfate column, and eluted with 9:1 hexane:methylene chloride. Analysis proceeded as with milk samples.

Quality assurance. Quality assurance/quality control procedures were followed as specified in standard methods (1). A method blank accompanied each batch analysis of four to six samples, and 10% of samples was analyzed in duplicate. All samples were spiked prior to clean-up with a ^{13}C -labeled mixture of the 17 2,3,7,8-substituted PCDD/PCDF congeners and 12 PCBs (PCBs 77, 126, 169, 28, 47, 52, 101, 118, 153, 180, 194, and 209) as internal standards, as well as two ^{12}C -labeled surrogate standards for the GC-ECD determination of pesticides (tetrachloro-*m*-xylene and PCB 210). For pesticide analyses, matrix duplicates and matrix spike duplicates were used in alternate batches (10%). Precision was expressed as the relative percent difference (RPD) and accuracy as the percent recovery of the labeled internal standard.

Statistical analysis. Analytical data were stored in EXCEL 5.0 (Microsoft, Redmond, WA), and questionnaire data were stored in EpiInfo 6 (CDC EpiInfo, Atlanta GA). Both databases were transferred to SYSTAT (SYSTAT, Inc., Evanston, IL) for statistical analysis.

Distributions of the concentrations of each chemical compound in milk samples were examined for symmetry, skewness,

multimodality, etc. The correlations of the various compounds with each other were examined by scatter plots and correlation coefficients, either the parametric Pearson correlation or the nonparametric rank correlation. Contaminant distributions were compared across geographic regions and across dietary habits to test for statistically significant differences. For human breast milk, all concentrations were tested for normality and were found to be skewed, requiring a natural log transformation to achieve normality. Analysis of variance (ANOVA) with Bonferroni adjustment was used to compare mean concentrations (transformed to their natural logs) among the sampling areas.

Results

Table 1 shows the summary statistics of mothers' and infants' ages and ethnicity, and infants' birth weight and sex.

PCBs were measured in 35 breast milk samples and 3 duplicate samples. Results were expressed as 1) total PCBs, i.e., the sum of 80 individually measured congeners; 2) the sum of six prevalent marker PCBs that are reported in the literature (PCBs 28, 52, 101, 138, 153, and 180); and 3) PCB-TEQs based upon the WHO-TEQ system (4). RPDs for the six marker PCBs were between 20 and 30%. Results are shown in Table 2 (by sampling site and for entire data set). The sum of the six prevalent PCBs averaged 180 ng/g fat for the entire data set. The average level for Atyrau (430 ng/g fat), however, was well above averages for other areas ($p < 0.001$). Additionally, the highest PCB-TEQ (46 pg/g fat) was in Atyrau ($p < 0.05$).

Organochlorine pesticides were analyzed in 76 breast milk samples, 13 duplicates, and 6 matrix spike duplicates. RPDs were below 5% for duplicates and 13% for matrix spike

duplicates. Recoveries averaged 87%. Results are shown in Table 2. The rural area and Atyrau had the highest levels of most OCs.

All fish and dairy products had very low levels of the target analytes (traces of β -HCH and DDE up to 35 ng/g), with the exception of fish (vobla) from Atyrau. Those fish had total PCBs up to 250 ng/g.

Discussion

Study population: participation rates and selection bias. All births and pre- and post-natal care occurred at the regional MCHCs of Kazakhstan's national health care system. This enabled MCHC staff to contact all healthy first-time mothers with 2–8-week-old infants living in their region. According to MCHC staff, most of the eligible women that were contacted agreed to participate, but selection bias cannot be ruled out.

Demographics. The population of Kazakhstan is 46% Kazak, 35% Russian, and 20% other (including Turks, Uzbeks, Koreans, Germans, Ukrainians, and Gypsies). Russians are more prevalent in the north (70–80% of inhabitants), and Kazaks are more prevalent in the south (80–90%). Ethnicity (Kazak vs. Russian) was used as a surrogate for dietary and lifestyle habits. The ethnic composition of the sample population closely matched that of the targeted regional population (see Table 1). Very few of the mothers were cigarette smokers (practically none outside of Almaty), and those that did smoke only reported smoking 1–3 cigarettes/day. There were no statistically significant differences among average birth weights from different sampling sites.

Analytical results. Selected samples of fish, cow's milk, and soil were analyzed. Surface soil samples collected in the vicinity of a refinery and storage bins of a cotton mill showed no unusual chemical profiles. In the fish samples, coplanar PCB levels were elevated as compared to levels recently measured in fish taken from the San Francisco Bay in California (5). The highest total PCB concentrations were measured in vobla fish from Atyrau. In cow's milk, the organochlorine pesticides *p,p'*-DDE and α -, β -, and γ -HCH were present at the nanogram per gram fat level. The other target pesticides were below the 20–30 ng/g fat reporting limit. Total PCB levels varied over 10-fold among cow's milk samples.

No statistically significant differences were found between geographic areas and infant birth weight, infant sex, or maternal age. Additionally, no statistically significant correlations were found between chemical concentrations in breast milk and infant birth weight or maternal age, probably because the ranges of maternal age and birth weight were quite narrow and the sample size small (Table 1).

Table 1. Summary statistics for demographic variables

Variable	Number	Percent	Minimum	25%	Median	75%	Maximum	Mean \pm SD
Ethnicity								
Kazak	49	64.5						
Russian	22	28.9						
Other	5	6.6						
Total	76							
Infant sex								
Female	33	43.4						
Male	43	56.6						
Total	76							
Maternal age (years) <i>n</i> = 76			16	19.5	22	25	34	22.5 \pm 3.8
Infant age (weeks) <i>n</i> = 75 ^a			1.6	4.3	6.1	7.6	10.4	6.0 \pm 2.2
Infant body weight (g) <i>n</i> = 73 ^a			1,300	3,000	3,300	3,600	4,450	3,220 \pm 530

SD, standard deviation.

^aSome information is missing.

Comparing data from this study with chlorinated residue data from other breast milk studies is problematic for several reasons. First, studies that are truly cross-sectional, and attempt to determine region- or country-wide contaminant levels, are rare. Second, most studies have employed different selection protocols (e.g., instead of the WHO/EURO protocol, selection criteria may be the age of mother, age of infant, parity, or other factors associated with residue levels). In addition, the new congener-specific PCB analytical methodology introduced in this study contrasts with the generic mixture data (e.g., Aroclor or Clophen) reported elsewhere. Thus, our comparisons are limited to selected PCB data from two WHO-sponsored studies and several small studies (1,6–11).

PCBs. Total PCBs shown in Table 2 are the sum of 80 PCB congeners measured individually (3). This definition of total PCBs makes comparisons among studies difficult because different congeners are measured in each laboratory. However, as discussed elsewhere (3), over 80% of the total PCBs in this study derive from the 12 most prevalent congeners that are usually measured by all researchers. Total PCB levels measured in this study in breast milk are lower than PCB levels found in industrialized countries (3). [See She et al. (3) for details of PCB congener profiles.] Total PCB levels in samples from Atyrau were much higher (mean = 820 ng/g fat) than in samples from other study areas ($p < 0.001$).

Data on the six prevalent PCBs have been reported extensively and can be compared across studies. Possible sources of the elevated PCB exposures in the Atyrau area may be local industrial activities (refineries) or the combination of local and distant activities affecting the area throughout the Ural River Delta. Fish consumption is a plausible exposure pathway; the highest

PCB levels were measured in two composite breast milk samples from women who indicated moderate (one composite) and daily (one composite) consumption of fish. Fish from Atyrau had up to 250 ng/g total PCBs.

The six prevalent PCBs were summed in the two WHO breast milk reports (1,6). In the 1989 WHO study (1), among comparable data sets that use similar analytical methods, the highest concentrations (sum of six congeners = 400–750 ng/g fat) were reported from (West) Germany, the Netherlands, and Belgium. Lower levels (200 ng/g fat) were reported from Finland and the United States, and the lowest levels were measured in Vietnam and Thailand (100–200 ng/g fat). Kazakhstan milk samples bracket these extremes. The levels of the six PCBs in milk from Atyrau fall within the range of industrialized European countries, while levels at other sites resemble those typical of Asian countries.

The preliminary 1994 WHO summary (6) is based on milk samples collected in 1993, i.e., 5 years after the first WHO study described above (1). Among the countries sampled, the Czech and Slovak Republics had the highest sum of the six PCBs (>1,000 ng/g fat), whereas Pakistan, Hungary, and Albania had the lowest (<100 ng/g fat).

Another source for comparison is a recent study from eastern ($n = 497$) and western ($n > 1,000$) regions of Germany, where the sum of the same six congeners was reported (7). With one exception (an industrial region in eastern Germany), participants had no known exposure (occupational or environmental) to PCBs; these levels were considered background. The maximum sum in eastern Germany (305 ng/g fat) was lower than the average reported for western Germany (590 ng/g fat).

The WHO-TEQ values (4) for the Kazakhstan PCB data set was calculated

Table 2. Mean and standard deviation (SD) of selected analytes in breast milk

Analyte	All		Almaty		Aralsk		Atyrau		Shymkent		Qzyl-Orda		Rural		p-Value
	Number	Mean	Number	Mean	Number	Mean	Number	Mean	Number	Mean	Number	Mean	Number	Mean	
α -HCH	74	78 (80)	18	41* 33	8	97** (49)	11	68 (31)	15	67 (43)	9	75 (30)	13	82 (88)	<0.002
β -HCH	76	2,210 (1,412)	19	1,660* (610)	8	2,690 (1,840)	11	1,570* (740)	15	2,910 (1,640)	9	2,040 (1,120)	14	3,470** (1,900)	<0.001
HCB	76	91 (69)	19	98* (40)	8	178* (155)	11	90 (26)	15	52** (18)	9	77 (42)	14	118* (99)	<0.005
DDE	76	1,960 (1,580)	19	1,800 (1,270)	8	1,540 (890)	11	3,400 (2,820)	15	1,400* (960)	9	1,240* (740)	14	3,330** (1,620)	<0.001
DDT	75	300 (216)	19	224## (197)	8	506*# (306)	11	460*# (305)	15	148*** (70)	9	386* (244)	14	297* (114)	<0.001
DDE/DDT	75	9.3 (13)	19	9.2*# (5.9)	8	3.6** (1.8)	11	14.6 (30)	15	9.7*# (7.2)	9	3.6## (2.2)	14	12*# (6.2)	<0.001
TOT-PCB	33	380 (280)	1	435 NA	7	328* (104)	6	817** (259)	6	313* (189)	5	278* (123)	8	216* (63)	<0.001
6-PCB	35	180 (160)	2	186 NA	7	140* (38.7)	6	427** (254)	7	144* (91.8)	5	101* (30.4)	8	107* (35)	<0.001
PCB-TEQ	35	22 (20)	2	24.4 NA	7	19.8 (11)	6	45.9** (36.7)	7	17.4 (6.3)	5	8.6* (6.3)	8	18.2 (15.3)	<0.05

Abbreviations: HCH, hexachlorocyclohexane; HCB, hexachlorobenzene; PCB, polychlorinated biphenyl; TOT-PCB, total PCBs; 6-PCB, sum of 6 PCBs; PCB-TEQ, PCB toxic equivalents. Values are given in nanograms per gram fat except for PCB-TEQ, which is given in picograms per gram fat.

** or ## indicate sites that had significantly different levels from sites marked by * (or #) at the cited level of significance.

using the three coplanar PCBs (PCBs 77, 126, 169) and PCBs 105, 118, 123, 156, 170, and 180. As can be seen from Table 2, PCB-TEQ values for Kazakhstan averaged 22 pg/g fat, which is similar to TEQs of industrialized western European countries: The Netherlands, 36 pg/g fat (9) and 20 pg/g (11); Sweden 22 pg/g (10); Norway 22–32 pg/g (8); and Lithuania, 32 pg/g (8). Atyrau, as discussed above, had significantly higher levels (46 pg/g fat), mostly due to mono-*ortho* PCBs (Hooper et al., in preparation).

Organochlorine pesticides. Breast milk samples were analyzed for 19 common organochlorine pesticides. Of the 76 samples analyzed for OC pesticides, practically all had measurable levels of *p,p'*-DDE (100%), β -HCH (100%), HCB (100%), *p,p'*-DDT (99%), and α -HCH (98%). Fewer samples had measurable levels of *o,p'*-DDT (12%), aldrin or *o,p'*-DDE (5%), γ -HCH or *p,p'*-DDD (4%), endosulfan-II or oxychlordane (2%), and *trans*-nonachlor or mirex (1%). Not detected (<10 ng/g fat) were heptachlor, heptachlor epoxide, dieldrin, endrin aldehyde, methoxychlor, α - and γ -chlordane, chlordecone, and *o,p'*-DDD. It appears that members of the chlordane family have not had major use in the areas sampled.

Residue levels [mean and standard deviation (SD)] of *p,p'*-DDE, β -HCH, HCB, *p,p'*-DDT, and α -HCH in each of the six sampling areas and the entire study, as well as the DDE/DDT ratio, are shown in Table 2. One sample had nondetectable levels of α -HCH and another had nondetectable DDT.

For HCB, the breast milk levels in

Shymkent were lower ($p < 0.005$) than those in Almaty, Aralsk, and the rural area. The rural area had higher ($p < 0.001$) levels of *p,p'*-DDE than did Shymkent and Qzyl-Orda and higher levels ($p < 0.001$) of β -HCH than Almaty and Atyrau.

In the United States, commercial DDT is a mixture of *p,p'*-DDT (70–90%), *o,p'*-DDT (10–20%), and lesser amounts of degradation products (*p,p'*-DDE, *o,p'*-DDE, and *p,p'*-DDD). All tend to bioaccumulate (persist) to varying degrees in tissues. *p,p'*-DDE, the main metabolite of *p,p'*-DDT, is the major contaminant in human milk, persisting longer than DDT. Where DDT use is banned, DDT levels in milk decline with time, and the ratio of *p,p'*-DDE to *p,p'*-DDT increases. A DDE/DDT ratio of <1–5 indicates recent exposure to parent DDT. A ratio >5 indicates that the DDT residues arise from the food chain (12).

In the present study, the lowest levels of *p,p'*-DDT were in Shymkent, and the differences were statistically significant ($p < 0.001$) for all areas except Almaty. The two highest *p,p'*-DDT levels were in Aralsk and Atyrau. The low DDE/DDT ratio in Aralsk suggests continuing exposures to DDT, possibly from pesticide-laden dust blowing from the dry lake bed. In contrast, the higher DDE/DDT ratio in the rural region suggests a curtailed use of DDT on cotton crops and its persistence in the food chain.

Levels of *p,p'*-DDE in this study were between 240 and 10,540 ng/g fat, with a mean of 1,960 ng/g fat. This compares with the 1970s–1980s worldwide average of 2,000 ng/g (12). Levels of *p,p'*-DDT were

between 75 and 1,030 ng/g fat, with a mean near 300 ng/g fat. The DDE/DDT ratio ranged between 1 and 105, indicating variability in recent exposures to DDT. The DDE/DDT ratios in Aralsk and Qzyl-Orda were lower than in Almaty, Shymkent, and the rural areas ($p < 0.001$), suggesting a continuing DDT exposure in Aralsk (see above).

Many earlier studies reported only total DDT because the analytical methods could not distinguish DDT metabolites. In the late 1980s, worldwide total DDT averaged 1,000 ng/g fat, with levels in developing countries 10–100 times higher (12). In the 1970s–1980s, worldwide levels of *p,p'*-DDE averaged 2,000 ng/g fat, with a maximum at 20,000 ng/g fat. More recent data from Germany (7) showed concentrations mostly below 2,000 ng/g fat.

The HCH family of chemicals is a mixture of isomers, the most prominent of which are the α -, β -, γ -(lindane), and δ -isomers. Of these, β -HCH is the most persistent and selectively bioaccumulates in tissues. Levels of β -HCH ranged from 430 to 8,600 ng/g fat, with an overall average of 2,210 ng/g fat (Table 2). The β -HCH levels in the rural area were significantly higher (3,470 ng/g fat, $p < 0.001$) than those measured in Atyrau and Almaty. These levels are clearly above the background level for Europe (200 ng/g fat) and are among the highest levels recorded (12). Recent β -HCH residue data from eastern regions of Germany averaged 83 ng/g fat, with a maximum of 130 ng/g fat; samples from western regions of Germany averaged 75 ng/g fat (7). Consistently high β -HCH levels were reported in the early 1980s for

India (1,400–12,000 ng/g fat) and China (1,000–19,000 ng/g fat) (12).

γ -HCH (lindane) is applied on cotton in southern Kazakhstan five times during the growing season. Lindane (1% solution) is also used locally as a sheep or lamb dip for ticks twice a year (April and October).

Averaged hexachlorobenzene (HCB) levels in the human milk samples from southern Kazakhstan were below the world average of 100 ng/g fat (12). The highest HCB levels (15,000–20,000 ng/g fat) reported for breast milk resulted from accidental ingestion of poisoned grain in Turkey, and levels remained elevated for 30 years. High HCB levels were also reported in the early 1970s for Greece (7,000 ng/g fat), Spain (3,500 ng/g fat), and Australia (2,200 ng/g fat) (12).

Exposures to the nursing infant can be estimated using the WHO (1) suggested nursing scenario of 6 months duration, 0.7 l/day ingestion rate, and a milk fat content of 3.5% (13). Using the worst site and national average residue levels in Kazakhstan for DDE (3,330 and 1,960 ng/g fat, respectively) and DDT (500 and 300 ng/g fat, respectively) and assuming an infant weight of 5 kg, the combined DDE and DDT intake levels (18 and 11 μ g/kg/day, respectively) exceed the EPA reference dose (0.5 μ g/kg/day) and approach the allowable daily intake of the Joint Food and Agriculture Organization/WHO Meetings on Pesticide Residues (0–20 μ g/kg-day) (14). Intake levels of PCBs and dioxins by the nursing infant will be discussed elsewhere (Hooper et al., in preparation).

Conclusions

This is one of very few studies that examined such a broad panel of chemicals in a systematic way, following the widely accepted WHO protocol. Additionally, this is the first thorough investigation of chlorinated contaminants in Kazakhstan. Representative samples were collected from a multiethnic population from a large region, and the findings provide insights into body burdens

carried by people in this region. The major findings are as follows:

- Overall β -HCH levels (2,210 ng/g fat) are much higher than what is considered background in Europe (200 ng/g fat), with the highest levels found in the rural areas (3,470 ng/g fat)
- Overall p,p' -DDE levels (1,960 ng/g fat) are similar to the world average in the late 1970s (2,000 ng/g fat), higher levels were found in the rural areas (3,330 ng/g fat)
- HCB levels were similar to world average levels (100 ng/g fat)
- Overall PCBs, expressed both as total PCBs (380 ng/g fat) and as the sum of six PCBs (180 ng/g fat), were lower than those reported from industrialized European countries (400–1,000 ng/g fat). Average levels from Atyrau (total PCBs = 820 ng/g fat, six PCBs = 430 ng/g fat), however, were similar to those countries
- The overall PCB-TEQ (22 pg/g fat) was similar to European countries (20–30 pg/g fat), with significantly higher levels in Atyrau (46 pg/g fat).

Clearly, industrialized regions like Atyrau should be further studied for PCB sources and pathways. Other industrialized cities in northern Kazakhstan should also be examined. Additionally, southern rural areas should be further studied and agricultural practices reviewed.

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